

Street Storage System for Control of Combined Sewer Surge

Retrofitting Stormwater Storage Into Combined Sewer Systems

by

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Foreword

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E. Timothy Oppelt, Director
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Abstract

A case study approach, based primarily on two largely implemented street storage systems, is used to explain the concept through construction and operation aspects of street storage systems. More specifically, the case studies address analysis and design approaches, the regulatory and funding framework, public involvement, construction costs, operation and maintenance procedures, and system performance.

Street storage refers to the technology of temporarily storing stormwater in urban areas on the surface (off-street and on-street) and, as needed, below the surface close to the source. Close to the source means where the water falls as precipitation and prior to its entry into the combined, sanitary, or storm sewer system. The idea is to accept the full volume of stormwater runoff into the sewer system but greatly reduce the peak rate of entry of stormwater into the system. System components include street berms, flow regulators, and surface and subsurface stormwater storage sites.

By eliminating or greatly reducing surcharging in combined sewer systems, street storage has the potential to cost effectively and simultaneously mitigate basement flooding and CSO's. Other possible benefits of street storage are mitigating SSO's, eliminating surface flooding, reducing peak flows at WWTP's, and controlling non-point source pollution.

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Abbreviations and Acronyms

CCI	Construction Cost Index (provided by ENR)
cfs	Cubic feet per second
CMP	Corrugated metal pipe
CSO	Combined sewer overflow
CSS	Combined sewer system
CUP	Chicago Underflow Plan
CWA	Clean Water Act
DPW	Director of Public Works
EDA	U.S. Department of Commerce Economic Development Administration
ELSSD	Emerson-Lake Streets Sewer District
ENR	Engineering News-Record (Source of the CCI)
EPA	Environmental Protection Agency (same as USEPA)
gpd	Gallons per day
HSSD	Howard Street Sewer District
HUD	U.S. Department of Housing and Urban Development
IDOT	Illinois Department of Transportation
IEPA	Illinois Environmental Protection Agency
ILLUDAS	Illinois Urban Drainage Area Simulator
ITE	Institute of Transportation Engineers
mph	Miles per hour
MSDGC	Metropolitan Sanitary District of Greater Chicago (now the MWRDGC)
MSSD	Main Street Sewer District
MWRDGC	Metropolitan Water Reclamation District of Greater Chicago (formerly MSDGC)
NMC	Nine minimum controls
POTW	Publicly-owned treatment works
RHS	Rural Housing Service
RUS	Rural Utilities Service
SAM	System Analysis Model
SASAM	Surface and Street Analysis Model
SRF	State Revolving Fund
SSS	Sanitary sewer system
SWMM	Storm Water Management Model
TARP	Tunnel and Reservoir Plan
USDA	U.S. Department of Agriculture

USEPA	U.S. Environmental Protection Agency (same as EPA)
WWF	Wet weather flow
WWTF	Wastewater treatment facility

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CHAPTER 1

INTRODUCTION

Combined Sewer System Challenge in the U.S.

Much work remains to be done to solve the overflow and basement flooding problems caused by surcharging of combined sewer systems (CSS) in approximately 1000 U.S. communities. These communities, 60% of which are small in that they have populations of less than 10,000, have a total population of about 40 million or approximately 15% of the country's total. About 85% of the CSS municipalities are in eleven northeastern, midwestern and far western states. Within these communities are 10,000 combined sewer overflow (CSO) points and an unknown number of historic and potential basement flooding situations (Dwyer, T. 1998).

Most combined sewer municipalities face the challenge of how to mitigate overflows and/or basement flooding and the attendant water pollution, health risks, and monetary damages. The challenge is further defined by recognizing that the combined sewer problem must be solved to comply with state and federal regulations, recognize the realities of fiscal responsibility, and earn public acceptance.

Presented in this manual is a description and evaluation of what has proven, within a specific set of circumstances, to be one way of meeting the CSS challenge. More specifically, the technology described in this manual solved surcharging, complied with regulations, proved to be cost effective and earned public support.

CSO Policy of the USEPA

Objectives of the Policy

Three objectives guide the U.S. Environmental Protection Agency's (USEPA) CSO policy (USEPA 1994). They are:

- "...ensure that if CSOs occur, they are only as a result of wet weather."

- “...bring all wet weather CSO discharge points into compliance with the technology-based and water quality-based requirements of the Clean Water Act (CWA).”
- “...minimize water quality, aquatic biota, and human health impacts from CSOs.”

According to the USEPA (1994):

Permittees with CSSs that have CSOs should immediately undertake a process to accurately characterize their sewer systems, to demonstrate implementation of the nine minimum controls, and to develop a long-term CSO control plan.

Nine Minimum Controls

Permittees with CSOs should, according to the EPA (1994), submit appropriate documentation demonstrating implementation of the nine minimum controls (NMCs), including any proposed schedules for completing minor construction activities. The nine minimum controls are:

2. proper operation and regular maintenance programs for the sewer system and the CSOs;
3. maximum use of the collection system for storage;
4. review and modification of pretreatment requirements to assure CSO impacts are minimized;
5. maximization of flow to the publicly-owned treatment works (POTW) for treatment;
6. prohibition of CSOs during dry weather;
7. control of solid and floatable materials in CSOs;
8. pollution prevention;
9. public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts; and
10. monitoring to effectively characterize CSO impacts and the efficacy of CSO controls.

John and Wheatley (1998) focus on the minimum and interim aspects of the NMCs when they state that the NMCs were:

...not expected to require major capital expenditures and directed state environmental agencies to formulate their own strategies for bringing CSOs into compliance with water quality standards and other CWA requirements. The minimum controls can reduce CSO impacts on water quality but were not seen as a long-term solution.

Long-Term CSO Control Plan

Permittees with CSOs are, according to the EPA (1994), responsible for developing and implementing long-term CSO control plans that will ultimately result in compliance with the requirements of the CWA. The long-term plans should consider the site-specific nature of CSOs and evaluate the cost effectiveness of a range of control options/strategies. The minimum elements of the long-term control plan are:

- Characterization, monitoring, and modeling of the combined sewer system.
- Public participation.
- Consideration of sensitive areas.
- Evaluation of alternatives.
- Cost/performance considerations.
- Operational plan.
- Maximizing treatment at the existing POTW treatment plants.
- Implementation schedule.
- Post-construction compliance monitoring program.

Traditional Approach: Store/Treat Combined Sewage or Separate the Sewer System

Traditional and proven structural methods for resolving CSS flooding and pollution problems include, as shown in Table 1-1, separation, in-system storage, end-of-pipe storage, and deep tunnels. All the traditional solutions address the pollution problem while separation and in-system storage can also mitigate flooding problems, especially basement flooding caused by surcharging of combined sewers.

The premise of the traditional and proven solutions is to generally accept the rate of stormwater flow into the system. The resulting mixture of stormwater, sanitary sewage and other components is then controlled with methods such as in-system storage, end-of-pipe storage, and deep tunnels.

The Association of Metropolitan Sewage Agencies, in a study of 21 large U.S. communities having CSS's, reported that "storage is the most common approach taken to reduce the volume and frequency of overflows" (AMSA, 1994, p. 17). Storage in this context includes the in-system, end-of-pipe, and deep tunnels approaches listed in Table 1-1. Interestingly, nine of the 21 communities have constructed (Chicago, IL and Milwaukee, WI) or plan to construct tunnels. Two of the 21 studied communities, Minneapolis-St. Paul, MN and Hartford, CT have made major commitments to sewer separation.

Table 1-1. Proven methods are available to solve pollution and/or flooding problems in combined sewer systems.

Method	Problem Solved	
	Pollution	Flooding
Separation	✓	✓
In-System Storage ¹	✓	✓
End-of-pipe Storage ¹	✓	
Deep Tunnels	✓	

1) Storage of combined sewage.

A New Approach: Store Stormwater Before It Combines With Sanitary Sewage

Wet weather problems in CSSs are caused by the peak rate of stormwater runoff, not necessarily by the runoff volume. Wet weather flooding and pollution problems would often not occur, or would be much less severe, if the peak flows of stormwater could be lessened. Peak flows are often the principal culprit, not the volume of stormwater runoff.

This suggests a fundamentally different approach having the following premise: reduce the peak flow rates of stormwater before it enters the combined sewer system. Accept the full volume of stormwater into the CSS, but greatly reduce the peak rate of entry. Figure 1-1 illustrates, in conceptual fashion, this stormwater-oriented approach to reducing surcharging in CSS and, therefore, mitigating flooding and pollution. Chapter 3 includes a detailed description of the conceptualization, development, design and construction of the street storage approach.

Scope of This Evaluation

Case Study Approach

This manual documents a case study-based evaluation of the use of on-street and related storage of stormwater to reduce the surcharging of combined sewers and, in turn, mitigate basement flooding and CSOs. The focus of the evaluation is capturing, analyzing, and presenting what has been learned through the concept-through-operation process over 18 years in primarily two communities. Synopses of several other applications are included as supplemental ways to learn about the street storage system approach.

The scope of this manual is broad. The evaluation includes many and varied aspects of the case studies such as analysis and design approaches, regulatory and funding framework, public involvement, operation and maintenance procedures and costs, construction costs, and performance of the system. The scope of this manual is also deep, that is, detailed. Each of the preceding topics are covered in depth. The scope of this manual is also broad in that it addresses both flooding and pollution caused by surcharging of CSS's. This quantity and quality issue is discussed in the next section.

Quantity and Quality: Seeking Optimum Means of Simultaneously Mitigating Flooding and Pollution

Most CSS studies, reports and guidelines that are not community or site-specific, address only or mainly the need to reduce pollution caused by CSOs. Lost in this focus on pollution caused by surcharging of CSSs is the frequent parallel problem of basement and other flooding caused by surcharging of CSSs.

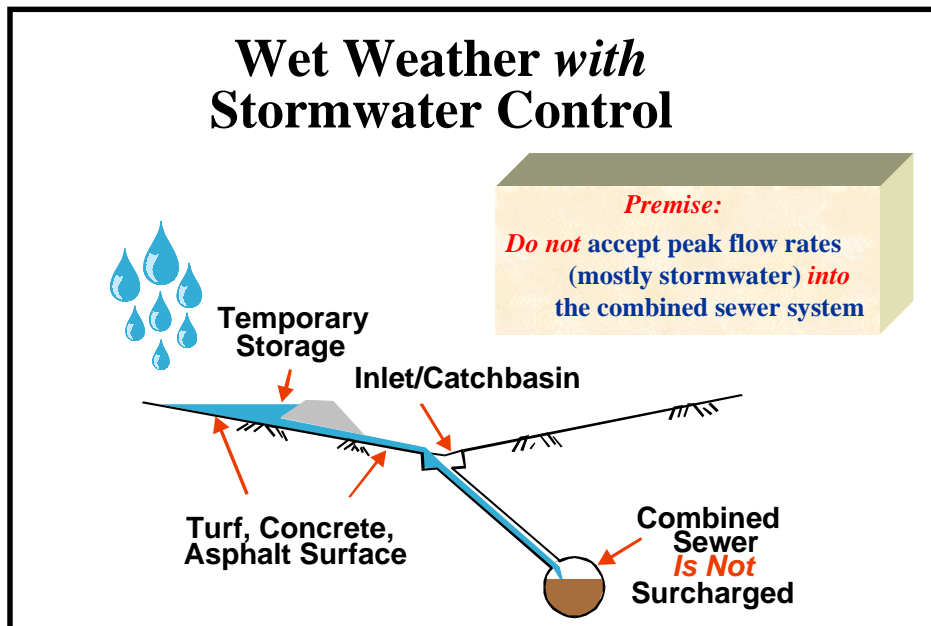
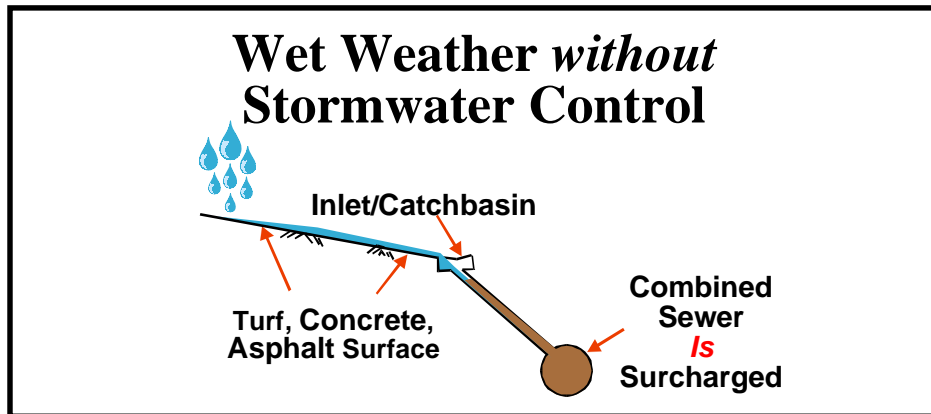
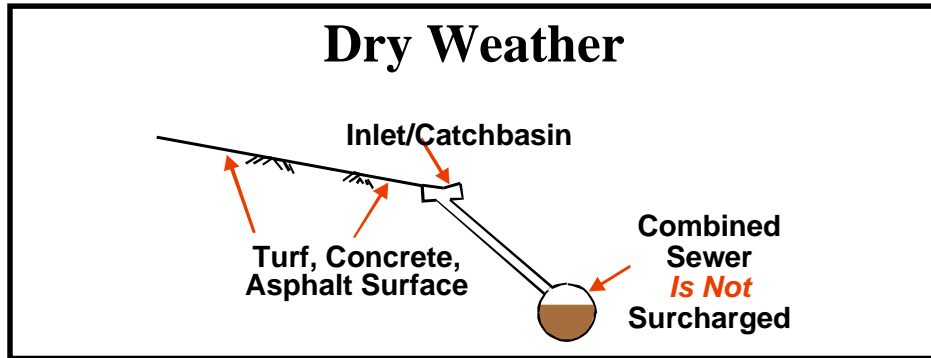


Figure 1-1. Control of peak rates of stormwater runoff can, in concept, mitigate surcharging of combined sewer systems.

As an indication of the possible local importance of basement and other flooding in CSS communities, consider the community-specific information provided in an assessment report prepared by the Association of Metropolitan Sewerage Agencies (AMSA, 1994). Described in this report are “CSO control programs” in 21 communities across the U.S. Although the focus of the report is clearly on CSS water quality, that is, pollution problems, water quantity problems, that is, flooding, are clearly evident in some of the 21 communities. The report states (AMSA, 1994, p. 15):

*In many of the cities, basement flooding during wet weather is also a problem that influences CSO improvements and **frequently impacts the selected control strategy (emphasis added).***

Flooding data on the previously mentioned 21 communities plus others is summarized in Table 1-2. Some type of flooding attributed to the CSS is explicitly reported by seven of the communities. Given the preceding quote, flooding problems may be under reported.

As an example of emphasis on pollution control in CSSs to the essential exclusion of flood control, consider the USEPA manual on combined sewer overflow control (USEPA, 1993). The stated purpose is to provide “...information to assist in selecting and designing control measures for reducing pollutant discharges from CSOs” (USEPA, 1993, p. 1). Although most of the report focuses on controlling combined sewage, there are scattered brief references to components of street storage. Examples are inlet restriction and attendant street ponding (p. 7), flow slipping (p. 7) and regulators (p. 38).

Several possible explanations can be offered for the strong focus on pollution caused by CSSs to the exclusion of addressing basement and other flooding problems.

First, pollution will almost always be a problem in CSSs while basement and other flooding problems are less likely to occur as evidenced by the AMSA (1994) assessment. Basements are essentially not present in some communities because of factors such as high groundwater levels and the presence of shallow bedrock. The actual severity and frequency of basement flooding, regardless of cause, is likely to be greater than reported because building owners may fear loss of property value if flooding of their basements is documented. However, when basements exist within a CSS, the resulting flooding by combined sewage can be a serious and repeated health risk and create large monetary losses.

Table 1-2. Seven of 22 large CSS communities explicitly reported basement or street and other surface flooding (AMSA, 1994 except where other source is indicated).

City	Type of Flooding Explicitly Reported As being Attributed to the CSS		
	Street and/or Other Surface Flooding	Basement Flooding	Undifferentiated Flooding
Atlanta, GA			
Boston, MA			
Chicago, IL		M	
Cincinnati, OH			
Cleveland, OH		M	
Columbus, GA			
Detroit, MI			
Fort Wayne, IN ¹		M	
Hartford, CT	M		
Louisville, KY	M	M	
Milwaukee, WI			
Minneapolis-St. Paul, MN			
New York, NY			
Philadelphia, PA			
Portland, OR			
Providence, RI			
Richmond, VA			
Sacramento, CA	M	M	
San Francisco, CA			
Seattle, WA			
Washington, DC			M
Wayne County, MI			

1) WERF, 1998, pp. 14-15

Second, the USEPA and counterpart state “environmental” agencies (e.g., Indiana Department of Environmental Management) tend to be concerned with pollution abatement. In contrast, flood control and drainage are within the mission of the COE and counterpart state agencies (e.g., Indiana Department of Natural Resources).

These flood control oriented agencies typically do not address problems in CSSs. Agency missions understandably drive agency programs. A possible negative aspect of exclusive or excessive focus on pollution abatement in CSSs is that less than optimum solutions may result. For example, a community’s CSO problem may be successfully resolved by end-of-pipe storage or end-of-pipe connection to “deep tunnels” while the basement flooding problem continues.

Optimum solutions are more likely to arise if the entire drainage system or watershed is examined from the outset in terms of defining the problem (pollution and flooding), determining the causes, and then finding the most cost-effective solution. The scope of this manual is holistic in that it stresses the possibility of simultaneously addressing quality and quantity, that is, pollution abatement and flood control.

Retrospective Details With Prospective Purpose

Because of the case study approach, the details of this manual are retrospective. That is, the emphasis is on history—what was done, why it was done, how it worked. However, in as much as municipal officials are the principal audience of this manual, the overall thrust is prospective. That is, how could other communities benefit from the concept-through-operation experience of the case study communities?

Each municipality has a unique meteorological, physical, socio-economic, political and regulatory profile. Therefore, only some of the knowledge gained from the case studies described in this manual will be transferable to any given community. However, given the breadth and depth of knowledge presented in this manual, if even a small part is directly applicable to a given municipality, that municipality will gain much. Stated differently, the specifics documented in this manual should prevent “reinventing the wheel” in other communities. The theme of relevance to other CSS municipalities is woven throughout this manual. Perhaps some communities will investigate the street storage option as a result of successes enjoyed by the case study municipalities.

In addition to having a prospective thrust to serve municipalities, this manual is also prospective for the benefit of researchers. Possible research topics are identified, (see Chapter 11), based on the case study experience, with the hope that additional investigations might be conducted.

Initiatives

As noted, this is a case study-based manual and, therefore, the details are largely retrospective. Accordingly, new research efforts were generally beyond the scope of the evaluation, with two specific exceptions.

The first exception to the retrospective focus of this manual is a literature search. Efforts were made to find, document and incorporate relevant papers, articles, and personal contacts not already discovered during the conduct of the two projects. Because the technology was considered innovative when first applied to the case study communities in the 1980's, a major effort was undertaken at that time to find relevant literature and knowledgeable individuals. Results of those efforts were included in early project documents and are summarized in this manual. The additional literature and resource search carried out for this evaluation was conducted to enhance the value of the manual. Findings of the literature search are included throughout this manual as supplements to the two case studies.

The second exception to the retrospective focus of this manual is the special analysis of the hypothetical impact of the control technology on the volume and frequency of CSOs and on peak flows at wastewater treatment plants. Basement flooding by combined sewage, not CSOs, was the major CSS concern in the two case study communities. However, the implemented solution may have the potential to mitigate CSOs and related problems. Therefore, that potential was studied in an exploratory fashion to further enhance the value of this manual. That study is described in Appendix F and the results are summarized in Chapter 9.

Terminology

Several terms have been used in recent years to describe controlling peak rates of stormwater flow as a means of reducing surcharging in CSS's. Utilization of different terms for essentially the same system can and probably has led to some confusion. Accordingly, various terms are discussed here for purposes of clarification and to show commonality among various research, development and engineering design efforts in the U.S. and elsewhere. A specific terminology and its definition is then set forth for use in this manual.

Terms in use include:

- **Runoff Control.** This terminology has been in use in the U.S. since at least the early 1980's. In fact, it was used in most of the written and spoken communication throughout the two principal case studies which are described in this manual. See for example, the numerous Donohue & Associates citations in the Cited References. However, this term, while suggesting stormwater, is too general. Many aspects of stormwater management could be called "runoff

control.”

- **Inlet Control.** This terminology appears in the title of writings by Hides (1994) and Pisano (1989) and is also used by Harza Engineering (1981). While inlet modification may be part of the overall stormwater control system, it is typically just one component. For example, other possible components are street berms and subsurface storage tanks. Therefore, the term inlet control is undesirable because it suggests an unrealistically simple approach.
- **Source Control.** This term, which was used by Kaufman and Lai (1978) and Walesh (1996), has appeal because the stormwater is to be temporarily stored as close as possible to the source, that is, to where it falls as precipitation. Unfortunately, this quantity-oriented use of “source control” conflicts with the predominantly quality-oriented use of “source control” in amendments to the Clean Water Act. In these amendments, “source control” is strongly associated with non-point source pollution.
- **Micromanagement of Stormwater.** This terminology, used by Carr and Walesh (1998), focuses on the local, detailed, intersection-by-intersection analysis and design process that is needed when attempting to reduce peak stormwater flows in existing urban areas. This analysis and the resulting design and construction of numerous, small structures may be characterized as “micro” when compared to the “macro” approach typically used in stormwater system analysis and design. “Macro,” in this context, refers to larger subbasins used in the analysis and the smaller number of larger structures, such as detention or retention facilities, typically designed and constructed. On the negative side, the term “micromanagement” is not, in and of itself, very descriptive. Additional description is needed to communicate the concept.
- **Street Storage.** This term has proved to be highly descriptive. It readily suggests the unconventional, but potentially effective use of streets to temporarily store stormwater. On the negative side, while on-street storage is typically an important aspect of reducing peak stormwater flow into a CSS, it is not the only form of storage. Other possibilities include off-street surface storage and storage below streets and parking lots. The short hand term “street storage” was selected for use in this manual. It appears in the title.
Street storage means:

a system that mitigates surcharging of CSSs, SSSs and stormwater systems by temporarily storing stormwater in a controlled fashion on the surface (mainly on-street but some off-street) and, as needed, below streets. Stormwater is stored close to the source, that is, where it falls as precipitation, and prior to its entry into the

sewer system. The full volume of stormwater runoff is accepted into the sewer system but peak rates are reduced, as a result of the storage, to flow that can be accommodated without surcharging.

Abbreviations, Acronyms and Glossary

Many abbreviations and acronyms are used, for the purposes of efficiency and communication, in this manual. In the interest of assisting the reader, the first use of an abbreviation or acronym in the manual is accompanied by its definition. After that introduction, the abbreviation or acronym is used in the remainder of the manual. For easy reference, a complete list of abbreviations and acronyms is included near the front of this manual.

Some readers may not be familiar with all the technical, regulatory and other terms used in this manual. Accordingly, a Glossary appears near the end of this document. Selected definitions were drawn from the “Glossary of Wet Weather Flow Terms” (USEPA, 1998) and from other sources, as indicated in the Glossary.